

Lesson 8: 7th grade
A Cursory Glance: The Four-Stroke Internal Combustion Engine

Lesson Overview: Learning the basic components of a four-stroke internal combustion engine.

Lesson Concept: Understanding basic combustion theory in order to develop a deeper understanding of how automobile emissions are created.

Materials:

- Student hand-out or overhead: Internal Combustion Engine Primer
- Note-taking journal
- Parent Information Letter

Standards:

- **English:**
 - **IX.11.MS.1** (Inquiry and Research: Define and investigate important issues and problems using a variety of resources).
- **Mathematics:**
 - **III.1.MS.1** (Data Analysis & Statistics: Collect and explore data through observation, measurements, surveys, sampling techniques and simulations).
 - **III.1.MS.4** (Data Analysis & Statistics: Identify what data are needed to answer a particular question or solve a given problem, and design and implement strategies to obtain, organize and present those data).
- **Science:**
 - **I.1.MS.1** (Construct new Scientific and personal Knowledge: Generate scientific questions about the world based on observation).
 - **II.1.MS.3** (Reflect on the Nature, Adequacy and Connections Across Scientific Knowledge: Show how common themes of science, mathematics, and technology apply in real-world contexts).
- **Social Studies:**
 - **IV.2.MS.4** (Economic Perspective: Examine the historical and contemporary role an industry has played and continues to play in a community).

Timeline: 2 – 5 class periods (40 – 50 minutes each)

Class Structure: reading assignment, small group project, and optional teacher-led demonstration

Assessment Strategy: EEK! Daily Assessment
General Assessment Strategy #2
General Assessment Strategy #3

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- Parent Information letter (optional potato rocket teacher led demonstration)

CLASS EXERCISES:

I. Four-Stroke Internal Combustion Engines

For the first part of the lesson refer to the Internal Combustion Engine Primer (*Internal Combustion Engines: a Primer*). If possible, introduce the components of the internal combustion engine to the students via an overhead. Also, if you have access to the technology resources, refer to the websites provided to watch animated drawings of four-stroke internal combustion engines.

II. Drawing the Engine: a small group project

- A. After you have introduced the information in the Primer, have the students, individually, draw an image of a four-stroke combustion engine from memory.
- B. Once everyone in the class has completed their drawings, divide the students into small groups.
- C. Ask the group members to compare their drawings with each other.
- D. Then, ask each small group to create one final image of a four-stroke combustion engine labeling as many parts of their engine drawing as possible.
- E. Hopefully, with the combined knowledge of all the group members, each group will create a close approximation to the information they learned earlier (in the Primer). If the students express confusion, encourage them to discuss what they have learned from the earlier lesson to tease out the information for themselves (independently or collectively).

III. Compare the Drawings

After each group has completed one drawing, pass out the Primer to each student. If necessary, ask the groups to correct and / or modify their drawings to reflect the basic components of a four-stroke combustion engine. Then, have the students securely place the Internal Combustion Primer in their Transportation Journals.

IV. Combustion Explained: Combustion Chemistry

This section discusses the basic chemistry of combustion. This exercise is an introduction to basic chemistry and chemistry concepts that will be later discussed in Lesson 9 (emissions, pollutants, and global warming).

V. Potato (Tennis Balls / Styrofoam Balls) Rockets *optional teacher led demonstration*****

Creating potato rockets is a direct and engaging way to show students exactly how energy dense gasoline is as a fuel. Also, it provides a visual for the ignition and exhaust parts of combustion. But, THIS IS A POTENTIALLY DANGEROUS EXERCISE! We have constructed this exercise as a teacher-led demonstration only with added exercises for student involvement.

Also, included at the end of the lesson is a PARENT INFORMATION LETTER. We suggest treating this letter as a permission slip for specific student participation in the experiment.

Internal Combustion Engines: a Primer



photo courtesy of Daimler Chrysler, 2003 Jeep Grand Cherokee Engine

A Brief History

In 1867, 34-year old Nicolaus August Otto created an invention that changed the world. The German engineer developed the four-stroke cycle engine. Dubbed the Otto-cycle this invention remains one of the most common engines used in cars and trucks today.

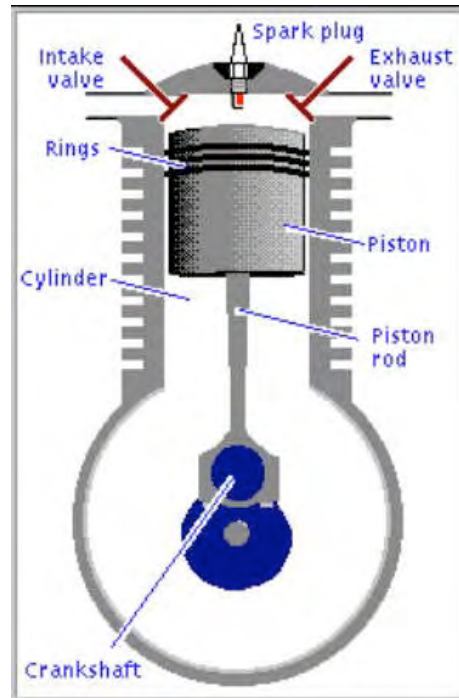
The Basics

The four-stroke engine is aptly named for it has four motions or “strokes”. The four strokes of the internal combustion engine occur in the following order:

- Intake
- Compression
- Power
- Exhaust

This process is continually repeated, always in this sequence, during the operation of the engine.

The Internal Parts

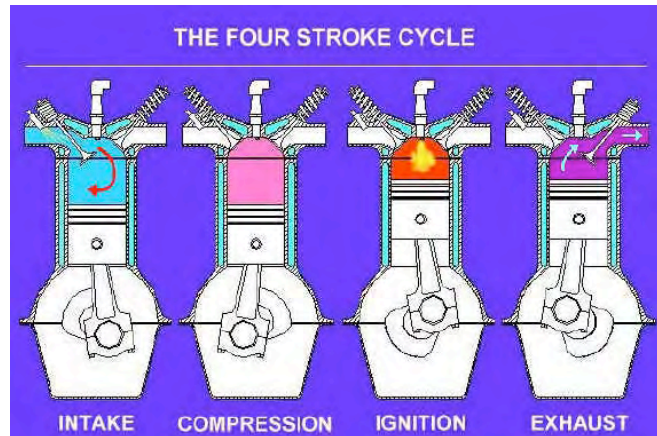


www.siu.edu/~autoclub/frange.html

Before explaining the operation of the four-stroke engine, some of the internal parts must be identified. Above is a drawing of the basic internal combustion engine. The description below is from *Back to the Basics: Fundamentals of the Four-Stroke Internal Combustion Engine* written by the Automotive Technology Organization at Southern Illinois University.

The Intake Valve opens at a precise time to allow the air/fuel mixture to enter the cylinder. The Exhaust Valve opens at a precise time to allow the burned gases to leave the cylinder. The Spark Plug ignites the air/fuel mixture in the cylinder, which creates an explosion. The force of the explosion is transferred to the Piston. The piston travels up and down in a Reciprocation Motion. The force from the piston is then transferred to the Crankshaft through the Piston Rod (connecting rod). The piston rod converts the reciprocating motion of the piston, to the Rotating Motion of the crankshaft. The four engine strokes require two revolutions of the crankshaft to complete one full cycle.

The Cycle Explained



www.antonine-education.co.uk/physics_a2/options/Module_7/Topic_4/internal_combustion_engines.htm

Please refer to the above diagram to help describe each of the four engine strokes. Also, the following websites have excellent animated drawing of internal combustion engines that provide a graphic visual explanation of the cycle:

- www.siu.edu/~autoclub/frange.html
- www.howstuffworks.com/engine.htm
- www.keveney.com/Engines.html

The Intake Stroke

During this stroke, the piston starts at the top, the intake valve opens, and the piston moves down to let the engine take in a cylinder full of air and gasoline. Given that gasoline is a very energy dense chemical compound, only a small amount (a drop) of gasoline needs to be mixed with air for the cycle to work properly.

The Compression Stroke

The piston moves back up to compress the fuel / air mixture. As this happens, the intake valve closes and the exhaust valve is closed creating a sealed cylinder chamber. When this mixture is compressed, it increases in temperature, which in turn will make the explosion more powerful.

The Ignition Stroke

When the piston reaches the top of its' stroke, the spark plug emits an electric spark and ignites the gasoline. The gasoline / air mixture burns rapidly and the cylinder pressure increases. All of this pressure in the cylinder continues to increase until it explodes. The force of the explosion drives the piston down. As the piston moves downward, force is transmitted to the piston rod which is connected to the crankshaft. The crankshaft is rotated due to the force.

The Exhaust Stroke

Once the piston hits the bottom of the stroke, the exhaust valve opens. As the piston moves upward, it forces the burned gases out of the cylinder through the exhaust port (the tail pipe). When the piston reaches the top of its travel, the exhaust valve closes, and the intake valve opens. The crankshaft has now completed two full revolutions and the cycle is complete. The engine is ready for the intake stroke, so it intakes another charge of air and gasoline.

The above explanation is taken from two articles: *Back to the Basics: Fundamentals of the Four-Stroke Internal Combustion Engine* written by the Automotive Technology Organization at Southern Illinois University and *How Car Engines Work* written by Marshall Brain.

IV. Combustion Explained: Combustion Chemistry

What is the Air Made Of?

Begin this section with the lead question: What is air made of?

- Write down all of the students' responses.
- How quickly you can cover this part of the lesson will be determined on the students' prior knowledge of chemistry—the information may be review or an introduction of new concepts.

The air we breathe consists mostly of the following gases:

Nitrogen (N ₂)	78%
Oxygen (O ₂)	20%
Other (argon, helium, water vapor, carbon dioxide)	2%

Essentially, the air we breathe mainly consists of N₂ and O₂.

Gases: Phase-Change

Oxygen and nitrogen are chemical elements in the gaseous phase. All chemical elements can be found in one of three phases. The three phases are: solid, liquid, and gas. For example, let's take a look at water. Water is frozen when in the solid phase, wet when in the liquid phase, and steam when it is in the gaseous phase. When temperatures of an element increase, the molecules of a substance part (are further away from one another) causing the substance to become less visible (or generally considered gaseous in non-scientific terms). This phase change causes air to be invisible. When the temperature decreases, the molecules are closer together. If the temperature decreases enough the substance will become solid. Elements change phases (or phase-change) at different temperatures.

Combustion Chemistry (a simplified version)

Oxygen (O₂) is an extremely volatile chemical element. If oxygen were the only component in the air on earth, everything would be constantly blowing up (igniting). This is where nitrogen comes into play, the nitrogen in the air acts as a buffer. But, when you want to burn something (a combustion reaction), the nitrogen has to go along for the ride (in air). Therefore, the nitrogen has to be heated. When the nitrogen gets hot, it is susceptible to reacting. In the case of air, when nitrogen is heated it reacts with the oxygen and becomes nitrogen oxide.

If there was perfect combustion in automobile engines, nitrogen oxides would not be a result of the combustion reaction. Below is the most simple, idealized combustion reaction—methane. Most fuels have carbon, hydrogen, and oxygen, but methane is the only fuel without oxygen present. The combustion reaction looks like this:



But, when driving a car, the combustion reaction takes place in the real world and oxygen is present.

Fossil fuels consist primarily of hydrocarbons. Hydrocarbons are atoms created from hydrogen and water. When hydrocarbons burn, the carbon combines with oxygen to produce carbon monoxide, carbon dioxide, nitrogen oxide, unburned hydrocarbons, and water.

Exhaust Pollutants

Hydrocarbons

Hydrocarbon emissions result when fuel molecules in the engine do not burn or burn partially. Hydrocarbons react in the presence of nitrogen oxides and sunlight to form ground-level ozone which is a major component of smog.

Nitrogen Oxides (NO_x)

Under the high temperature and pressure conditions of an engine, nitrogen and oxygen atoms in the air react to form various nitrogen oxides. Nitrogen oxides must be present to the formation of ozone and contribute to the formation of acid rain.

Carbon Monoxide (CO)

CO is a product of incomplete combustion and occurs when the carbon in the fuel partially, rather than fully, oxidizes.

Carbon Dioxide (CO₂)

CO₂ is a product of complete combustion and occurs when the carbon in the fuel is fully oxidized. CO₂ is a greenhouse gas that traps the earth's heat and contributes to global warming. Most important is: gasoline is energy dense & the combustion reaction are not perfect because you are carrying along all this nitrogen. But, others things are also happening.

Why use fossil fuels (gasoline)

Even though the combustion reaction is not perfect and creates large amounts of toxic emissions, gasoline has been the fuel of choice because it is an energy dense fuel source which means it only takes a small amount to cause a large reaction.

Building a Potato Rocket: Basic Plans, Experiments

I. Gasoline is an Energy Dense Fuel

Gasoline has a high energy content which means it takes only a small amount of gasoline to cause a large reaction. Gasoline is also highly flammable and toxic. If strong concentrations of gasoline are inhaled, this can cause dizziness, vomiting, and even death.

Building a Potato Rocket is an excellent visual demonstration of exactly how energy dense of a fuel gasoline really is: it takes only a drop of gasoline to launch a potato or tennis ball potentially 100 (or more) feet through the air.

This exercise is being suggested as a strictly teacher-constructed and teacher-led demonstration. Specifically, this means that **WE DO NOT RECOMMEND STUDENTS TAKING PART IN ANY ASPECT OF THE BUILDING OR FIRING OF THE POTATO ROCKET.**

This, therefore, is an optional exercise for the teachers depending on their prep time, interest level, and classroom climate. This exercise does provide an excellent opportunity for the students to hypothesize on potential outcomes as well as gain a first hand understanding of what the term “energy dense fuel” means.

All of the building supplies can be purchased at your local hardware store and camping store. Once constructed, the potato rocket should last many years and provide multiple class demonstrations.

II. Class Involvement

The day before the Potato Rocket Demonstration, have the students make hypotheses about the distance the potato / tennis ball will be launched. Write down all of the responses and have each student write down their predictions in their Transportation Journal.

Question #1: How far away do you believe the potato / tennis ball will land from the launching rocket?

Question #2: Make predictions for three different launches.

Question #3: Which do you believe would travel further: a potato or a tennis ball? Explain why.

III. The Day of the Launch

Before going outside, go over the class behavior expectations for the experiment. Then, assign the roles for the student assistants.

Student Assistants' Tools

- 100' measuring tape
- clipboards
- note-taking journals
- pencils
- erasers

Student Assistants' Roles

- Students will assist in measuring the distance the objects are launched, recording each measurement, and retrieving all launched objects.
- Students may also assist in carrying supplies (other than the gasoline or the potato rocket) to the experiment site.

IV. Comparing Results with Initial Hypotheses

The following day, discuss the results from the experiment and compare the results with their original hypotheses.

- Were the students surprised by the experiment? Why or why not? Explain in detail.
- How close were their original hypotheses to the actual distance launched?
- Discuss briefly the concept of an energy dense fuel—consider the amount of energy it takes to move a vehicle the size and weight of an automobile. Ask the following question:

Question #1: What might affect gas mileage in different vehicles. Discuss this question with the class and have them record their answers in the Journal.

Potato Rocket Plans

The following plans have been excerpted from the book *Backyard Ballistics* written by William Gurstelle. This is a fantastic resource for a variety of easy-to-use plans and well written descriptions for a variety of combustion science experiments.

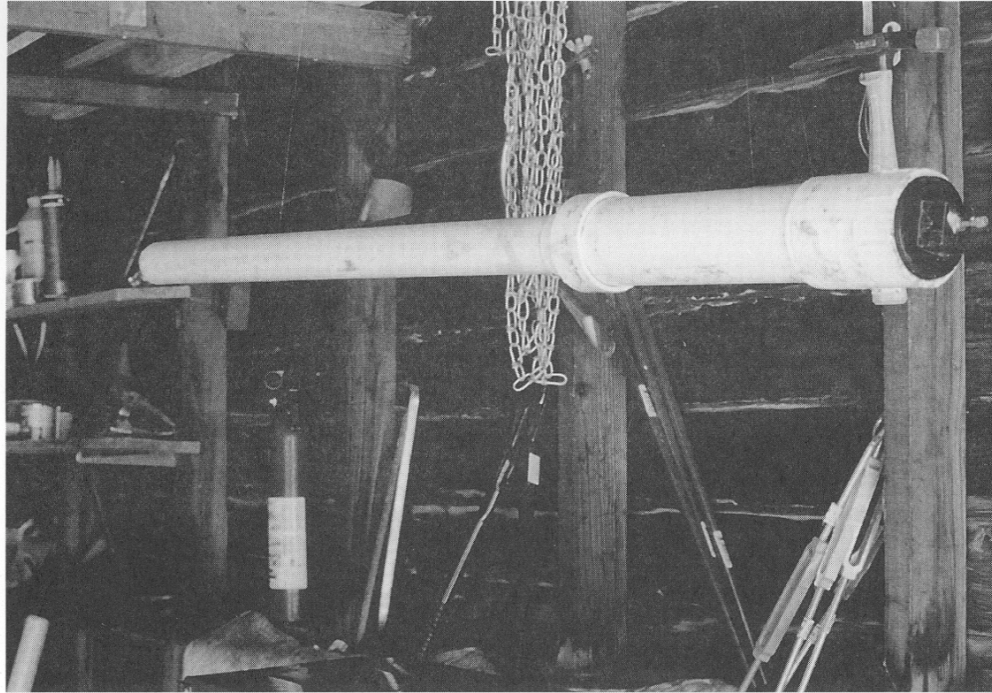
The following pages are taken from Chapter 2, The Potato Cannon, pages 7 – 22. This book is can be purchased directly through the webiste, www.backyard-ballistics.com or through Amazon.

Backyard Ballistics
Written by William Gurstelle
Chicago Review Press
2001
ISBN #1-55652-375-0

The Potato Cannon

The potato cannon, or spud gun as it is sometimes called, is nearly legendary in amateur science circles. You'll be amazed at how easy it is to make a working ballistic device out of materials readily available at your local hardware store. Don't worry, the potato cannon doesn't use dangerous gunpowder or rocket fuel to blast the potato in the air. Instead, the cannon takes advantage of the considerable energy contained within the aerosol propellant of common hairspray.

Thousands of people, from adolescent boys and girls to serious experimenters at Ivy League universities, enjoy shooting homemade ballistic devices like this. It's appealing for several reasons. First, the cannon is simple to build. Second, it really does work well. And finally, it's easy to understand. Unlike the complicated configuration of a computer's silicon chips, the average person can figure out (with the help of this book) the physics of the cannon.



2.1 Completed spud gun

People love making the potato cannon. Don't be too surprised if the hardware store clerk takes a quick look at your materials and says, "Making a spud gun, eh?" It happens to me all the time.

Building the Potato Cannon

Working with PVC Pipe

PVC pipe is the greatest home plumbing invention of the twentieth century. Unlike heavy steel pipe, the average person can quickly cut, join, and fasten PVC pipe with a minimum of materials and a small amount of practice. This makes it the perfect spud gun raw material.

THE PIPE

PVC pipe is made of a polyvinyl chloride plastic. Manufacturers make these pipes in various thicknesses. You specify the thickness by referring to its “schedule.” For our experiment, we need schedule-40 PVC pipe. It also comes in a variety of diameters: 1-inch, 2-inch, and so on. Buy it in 8-foot lengths and cut it to the size you need with a hacksaw.

THE CONNECTORS

PVC pipe manufacturers make a variety of connectors to join pipes in the way plumbers (and spud gunners) need. Couplings join pipes of similar sizes. Threaded couplings have female pipe threads cut into at least one end. Reducing bushings join a pipe of one size to a pipe of a smaller size. End caps simply cap the end of the pipe.

JOINING THE PVC

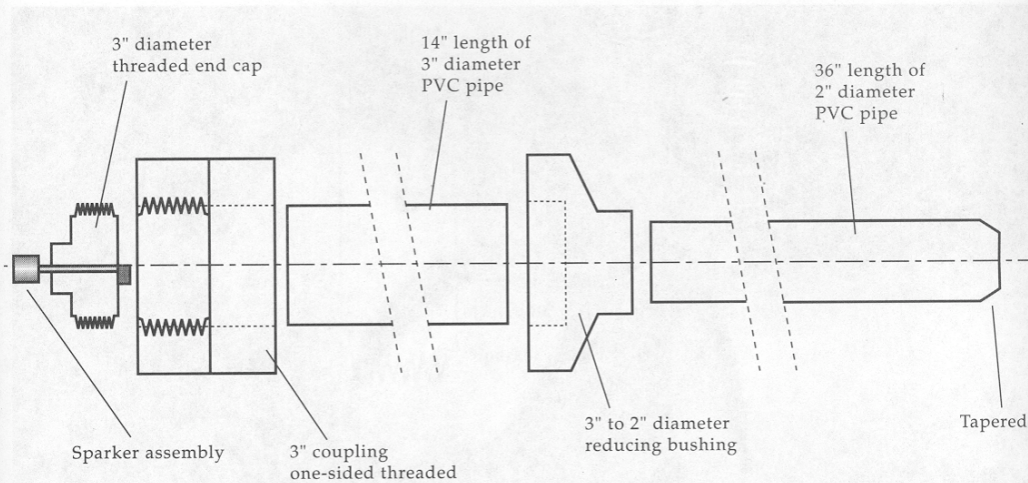
The insides of the connectors are either smooth or cut with screw threads. Sometimes we’ll want to join two smooth pieces, which can be “solvent welded” together using special PVC cement. (Note: Always use special-purpose PVC cement on PVC pipes and connectors. Regular glue won’t work.) Other times, we’ll want to join two threaded pieces that can simply be screwed together.

Go to the local hardware store’s plumbing section and ask the clerk to help you find the items on page 12. Yes, the big commercial hardware stores usually have all of these items (except the lantern sparker and hairspray). However, I recommend going to your local hardware store because the clerks are usually much more helpful. Sometimes, they will even cut the pipe to size for you and not charge you for a full 8-foot piece of pipe.

Materials

- ⊖ Hacksaw
- ⊖ Shaping file
- ⊖ (1) 36-inch length of 2-inch diameter schedule-40 PVC pipe
- ⊖ (1) 3- to 2-inch diameter reducing bushing
- ⊖ (1) 14-inch length of 3-inch diameter schedule-40 PVC pipe
- ⊖ (1) can PVC primer
- ⊖ (1) can PVC cement
- ⊖ (1) 3-inch coupling, one side smooth, one side threaded
- ⊖ Electric drill with $\frac{1}{8}$ -inch drill bit, $\frac{5}{16}$ -inch drill bit
- ⊖ (1) flint and steel lantern sparker. (This small device is widely available at most camping goods stores and large discount stores with camping equipment departments. It is designed to ignite the mantles of lanterns. It consists of a steel wheel that is rotated against a flint by means of a knurled brass handle. It generally retails for less than five dollars.)
- ⊖ Large adjustable wrench
- ⊖ Duct tape
- ⊖ (1) 3-inch diameter threaded PVC end cap
- ⊖ (1) 4-foot length of 1-inch diameter wooden dowel or broom handle
- ⊖ Hairspray in a large aerosol can (Be sure it's an aerosol can and not a pump spray. Spud gunners typically buy the most inexpensive brand of hairspray. Our interest is in its hydrocarbon propellant, not its holding power or scent.)
- ⊖ Protective gear including safety glasses, earplugs, and gloves
- ⊖ Bag of potatoes

THE POTATO CANNON



2.2 Assembly drawing

Place all of your materials and tools in front of you. Crafting a spud gun from raw materials takes at least two hours of filing, cutting, and drilling. You may need an extra pair of hands to hold things in place while you are gluing. After the pieces are put together, you'll need to let the PVC cement cure overnight.

1. Use the hacksaw to cut the PVC pipes to the desired lengths.
2. Use the file to taper one end of the long, 2-inch diameter pipe section so it forms a sharp edge. The edge will cut the potato as it is rammed into the muzzle of the gun.
3. Use PVC primer before cementing. Attach the 3-inch side of the 3- to 2-inch reducing bushing to one end of the 3-inch pipe using the PVC cement. Be sure the joints are clean and that you apply the cement according to the directions on the can. Don't forget to observe the



2.3 Applying the PVC cement

directions for curing times. You **MUST** let all the connections cure overnight in a well-ventilated area.

4. Carefully cement the smooth, unthreaded side of the 3-inch, one-sided threaded coupling to the 3-inch PVC pipe. Do not get any cement on the exposed pipe threads. If you do, you won't be able to screw the end cap into place.
5. The 36-inch long, 2-inch diameter pipe is the muzzle of the potato gun. Cement the untapered side to the 2-inch side of the reducing bushing.
6. Carefully drill a hole large enough for the sparker (usually $\frac{1}{4}$ inch or $\frac{5}{16}$ inch, but match the twist drill you use to the diameter of the sparker's hollow bolt) to snugly fit through the middle of the 3-inch threaded end cap.